Multiwavelength observations of the Be/X-ray binary 4U1145-619

J.B.Stevens[1], P.Reig[1], M.J.Coe[1], D.A.H.Buckley[2], J.Fabregat[3], I.A.Steele[4]
[1] *Physics and Astronomy Department, The University, Southampton SO17 1BJ*
[2] *South African Astronomical Observatory, P.O. Box 9, Observatory, 7935, South Africa*
[3] *Departmento de Astronomia, Universidad de Valencia, 46100 Burjassot, Spain*
[4] *Astrophysics Group, Liverpool John Moores University, Liverpool, L3 3AP*

Accepted
Received : Version 1 February 2008
In original form ..

ABSTRACT
We report optical and infrared observations of the massive X-ray binary system 4U1145-619 (V801 Cen) which show that the circumstellar disc of the Be star component is in decline. Infrared *JHKL* magnitudes of V801Cen have been monitored from 1993 March to 1996 April. Hα spectra have been obtained throughout the same period. We find that both the infrared excess and the Balmer emission have been in decline throughout the period of observations. A 13 year optical and X-ray history of the source has been collated, revealing a possible correlation between the optical and X-ray activity. In addition, we have used $uvby\beta$ indices, corrected for both circumstellar and interstellar effects, to calculate the physical parameters of the underlying B star.

Key words: stars: emission-line, Be - star: binaries - infrared: stars - X-rays: stars - stars: pulsars - stars: individual: V801Cen

1 INTRODUCTION

The Be/X-ray binary systems represent the largest subclass of High Mass X-ray Binaries (HMXB's). These systems consist of a compact object (usually a neutron star) in a wide eccentric orbit with a Be star. A Be star is defined to be an early type luminosity class III-V star, which has at some time shown emission in the Balmer lines (Jaschek, Slettebak and Jaschek 1981) . The Balmer emission, along with a significant infrared excess is believed to originate in the circumstellar material surrounding the Be star, probably in the form of an equatorial disc. The X-ray emission in these systems is the result of accretion of material onto the neutron star from the Be star's envelope. In the Be/X-ray systems, mass transfer is enhanced during periastron passage, as the neutron star passes through the denser regions of the companion's disc, resulting in X-ray outbursts with luminosities typically 10-100 times stronger than the quiescent level (Bradt & McClintock 1983) . In some cases outbursts are seen with no correlation to orbital phase (GRO J1948-03, Zhang et al., 1996; V0332+53, Terrel & Preidhorsky 1984). These outbursts are usually much more intense and are believed to be the result of large mass loss events from the Be star, although the mechanism behind such events is yet unclear.

The Be/X-ray binary 4U1145-619 is a highly variable X-ray source which has been optically identified with the 9th magnitude B1Ve star V801Cen (Bradt et al. 1977; Dower et al. 1978). White et al. (1978) found two X-ray pulsation periods of 292s and 297s from the field of the *Uhuru* source 4U1145-61, but were unable to confirm whether both periods originated in the one source, or whether there were in fact two X-ray pulsars within the field. The ambiguity was resolved when observations with the imaging proportional counter on the *Einstein Observatory* (Lamb et al. 1980; White et al. 1980) revealed the presence of two pulsars separated by 15′. The source identified with V801Cen (redesignated 4U1145-619) was found to pulsate with the 292s period, whilst the 297s period was found to originate in a new source, designated 1E 1145.1-6141, which was later found to be a member of the class of HMXB's with supergiant companions (Hutchings, Crampton & Cowley, 1981). Analysis of the long-term X-ray behaviour of 4U1145-619 revealed recurrent outbursts with a period of 186.5 days. Outbursts are typically of 10 day duration with flux levels increasing by a factor of $\sim$5 (Watson et al. 1981; Priedhosky & Terrell 1983; Warwick, Watson & Willingdale 1985). During the majority of the observed outbursts, the pulsed fraction of the total flux is relatively low. This, and the low luminosity of the source led White et al. (1983) to list 4U1145-619

Table 2. Optical spectroscopy of V801Cen. Errors in equivalent width measurements are typically 10 per cent

Date	Site	EW (Å)	
		Hα	Hβ
1993 Mar 2	SAAO	-38	
1993 Mar 4	SAAO		-4.5
1994 Mar 7	SAAO	-45	
1994 Jul 2	SAAO	-25	
1994 Jul 3	SAAO	-24	
1994 Jul 4	SAAO		-2.5
1995 Aug 24	SAAO	-27	
1996 Mar 2	AAT	-16	
1996 Apr 3	SAAO	-13	
1996 Apr 4	SAAO	-14	
1996 Apr 5	SAAO		-1.5

as one of the best approximations to a spherically accreting binary system. The accepted model for this system is that of a long period eccentric binary. The 186.5 day period in X-ray behaviour is then the consequence of phase dependant accretion from the Be star's circumstellar disc.

2 OBSERVATIONS

In this section we present our own infrared and optical observations made between 1993 March and 1996 April. These observations were made as part of the Southampton/Valencia/SAAO long term monitoring campaign of High Mass X-ray Binaries (Coe et al. 1993; Reig et al. 1996b). In addition, we present optical photometric data taken from the catalogue of ESO's Long Term Photometry of Variables (LTPV) project (Sterken et al. 1995 and references therein) covering the period 1982–1994, and a summary of previously published X-ray observations.

2.1 Infrared photometry

Infrared data were obtained on ten occasions between 1993 March and 1996 April, using the MkIII IR photometer on the 1.9-m Cassegrain Telescope at the SAAO. The chopping secondary mirror defines two effective apertures: on-source (star) and off-source (background). Square apertures of 9 or 12 arcseconds were used, depending on the seeing. The source was placed alternately in the two apertures for a number of cycles until a sufficient precision was reached. Observations were made in the SAAO *JHKL* system (1.25, 1.65, 2.2 and 3.5 μm; Carter 1990). A log of the observations, results and corresponding errors is presented in Table 1, and lightcurves are plotted in Figure 1. The results show a clear decline in all wavebands, with J decreasing by $\sim$0.4-mag, and L decreasing by $\sim$1.3-mag. In the same period of time, the J-K index has decreased by $\sim$0.5. Further discussion of the IR data is left until Section 4.

2.2 Optical spectroscopy

We observed the source ten times with the 1.9-m telescope at the SAAO between 1993 March and 1996 April, seven of these spectra were centered on Hα, the remaining three were taken at the blue end of the spectrum, to include Hβ. We also obtained a Hα spectrum from the AAT on 1996 March 2. The SAAO spectra were all taken with the ITS spectrograph and RPCS (Reticon) detector, with grating no.5, giving spectra covering the region 6000-6800 Å and 4400-5100 Å at 0.5 Å/pixel dispersion. Data were acquired in two channels (star and sky) simultaneously. The AAT spectrum was taken with the 82cm RGO camera and TEK 1K CCD, with the 1200R grating, giving a coverage of 6437-6677 Å at 0.234 Å/pixel dispersion. All data were reduced using the Starlink supported FIGARO package (Shortridge 1991).

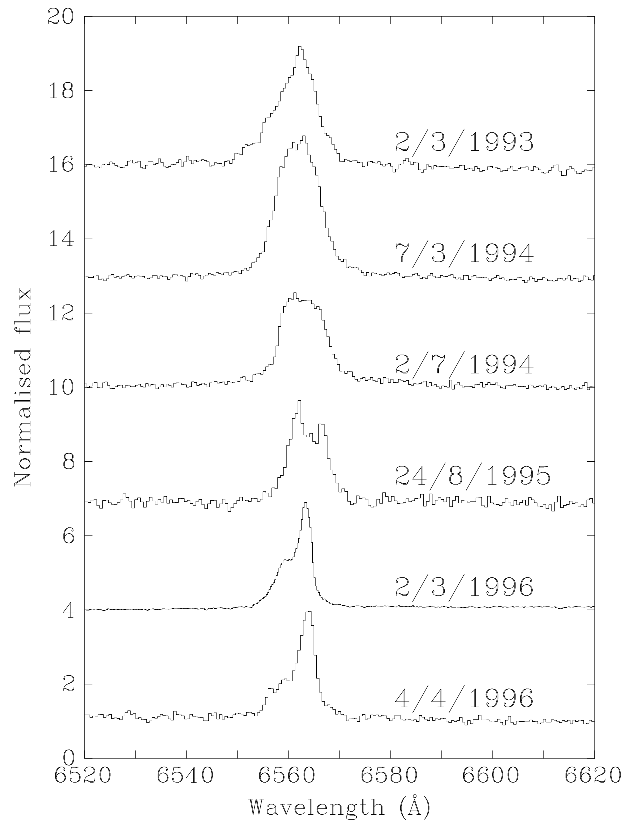

Figure 2. Hα profiles of V801 Cen, the optical counterpart to 4U1145-619. The March 1996 spectrum was obtained at the AAT, all other spectra are from the SAAO 1.9-m telescope. Fluxes are normalised to the continuum and offset from each other to allow comparison.

Table 2 shows a log of observations. Six of the spectra (centred on Hα) are shown in Figure 2. The Hα profile is generally asymmetric, and on one occasion (1995 August) shows a clear double peak, with V/R >1. There is a significant variation in the equivalent width of the Hα line. Throughout the period of observations, EW(Hα) has decreased by $\sim$70 per cent, compared to a typical uncertainty in a single value of $\sim$10 per cent. A decrease in the EW(Hβ) is also clear. The results are further discussed in Section 4.

Table 1. IR photometry of V801 Cen

Date	MJD	J	H	K	L	J-K
5 March 93	49052	8.24±0.03	7.93±0.03	7.53±0.02	6.98±0.05	0.71±0.04
8 March 93	49055	8.25±0.02	7.95±0.02	7.54±0.02	6.95±0.03	0.71±0.03
26 June 93	49165	8.42±0.02	8.10±0.02	7.67±0.02	7.07±0.05	0.75±0.03
5 March 94	49417	8.66±0.02	8.43±0.02	8.05±0.03		0.61±0.04
30 June 94	49534	8.482±0.011	8.268±0.011	7.955±0.007	7.464±0.017	0.527±0.013
21 February 95	49770	8.66±0.01	8.44±0.02	8.19±0.02		0.47±0.02
23 February 95	49772	8.67±0.01	8.45±0.01	8.19±0.01	7.70±0.06	0.48±0.01
17 August 95	49947	8.95±0.01	8.81±0.01	8.63±0.01		0.32±0.01
6 April 96	50180	8.682±0.028	8.562±0.009	8.395±0.011	8.279±0.058	0.287±0.030

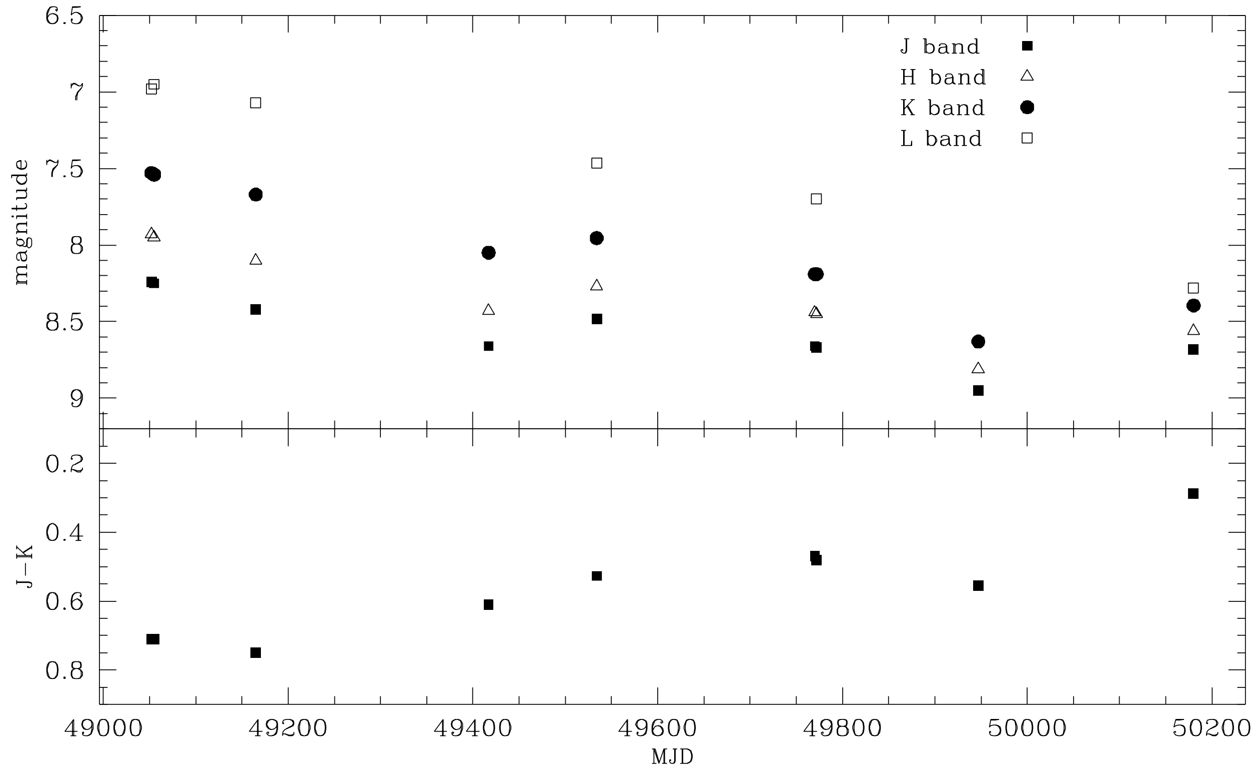

Figure 1. IR lightcurves of 4U1145-619 during the period 1993-1996. A complete log of observations and associated errors is found in Table 2.

2.3 Optical photometry

Strömgren *uvby* photometry was taken from the catalogue of the LTPV project (Sterken et al. 1995 and references therein) covering the period 1982–1994. In addition, broad V band photometry was taken from Pakull, Motch and Lub (1980, hereafter PML1980) and from Hammerschlag-Hensberge et al. (1980). The y data were transformed to standard V magnitudes using the transform given by Sterken et al. (1995). The data are plotted in Figure 3, along with infrared K band magnitudes and EW(Hα) values. The K band lightcurve consists of our data, plus data from Glass (1979) and from Waters et al. (1988). Hα values were taken from Cook and Warwick (1987b) to supplement our own data. The data from PML1980 show a rapid decline in optical luminosity during the first few months of 1980. A further optical minimum is clearly seen in 1984 February (MJD ∼46100), recovering to a maximum in 1990 April (MJD ∼48000). The flux in all bands has been in decline from this maximum until the date of the last observations.

2.4 X-ray flux history

An X-ray flux history has been compiled from the available literature. All data were transformed to 2–10 keV fluxes with the exception of the *EXOSAT* ME data which were given in this energy range originally. The 2–10 keV fluxes were calcu-

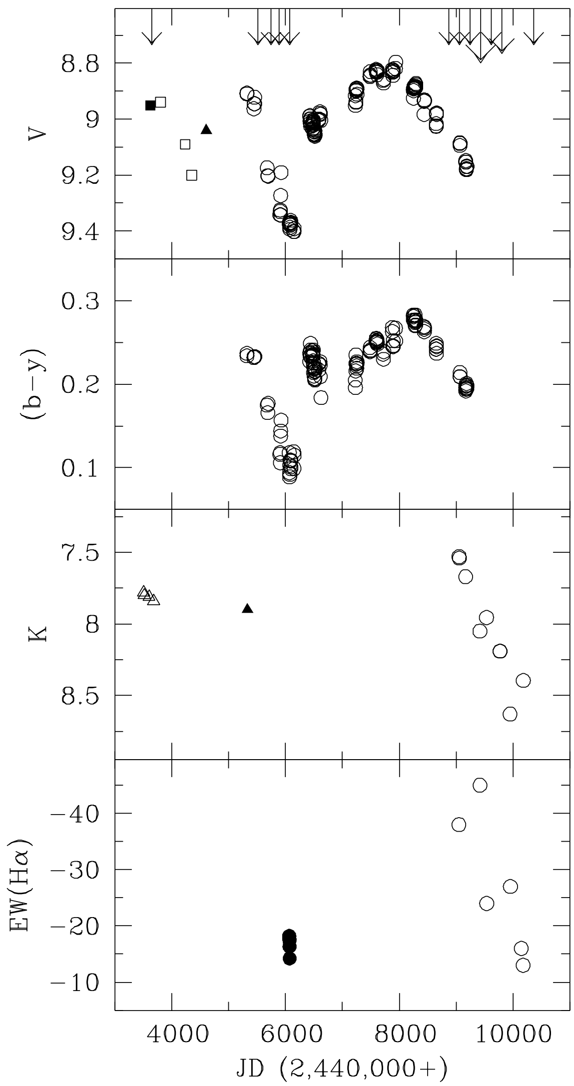

Figure 3. Top and second panel: Lightcurves of 4U1145-619 for the period 1978–1994, in Strömgren filter bands, Open squares represent data taken from Pakull et al. (1980), open circles represent data from ESO's Long Term Photometric Variable Project catalogues (Sterken et al. 1995), closed triangles those of Densham & Charles (1982), and closed squares represent data from Hammerschlag-Hensberge et al. (1980). **Third panel:** Infrared *K* band lightcurve from 1978–1996; the open circles represent our own data, the open triangles those of Glass (1979), and the closed triangles those of Waters et al. (1988). **Bottom panel:** EW(Hα) plot, 1978–1996. Open circles again represent our own data, closed circles those of Cook and Warwick (1987b). Arrows show the dates of detected X-ray outbursts, and are sized to give a crude indication of the intensity of the outburst.

lated assuming a power law spectrum with parameters derived wherever possible from the observations in question. This conversion is for comparison purposes only, and flux values may be in error by as much as a factor of two between one satellite and another. The 2–10 kev lightcurve is plotted in Figure 4. There is a quiescent flux of $\sim 10^{-10}$ ergs s^{-1} cm^{-2}, and for the sake of discussion we shall regard an increase by a factor of five in flux to be an outburst. The lightcurve then shows a number of outbursts, recurring at the 186.5 day period. Two of the outbursts stand out as the most luminous. The first, a 0.6-Crab (3–12 keV) outburst detected by the *Vela 5b* satellite in 1973 is clearly an order of magnitude more intense than the remaining outbursts, with the exception of a 0.5-Crab (20-40 keV) detection by the BATSE instrument on the *CGRO* satellite, in March 1994. BATSE has detected six outbursts from the source between MJD 48361 and 50231 (Scott M., private communication), though the one BATSE outburst plotted in Figure 4 was much more intense than the remaining five (Wilson et al. 1994; Scott M., private communication). The most recent X-ray detection is a 0.1-Crab (2-12 keV) outburst detected by the *RXTE* satellite's All Sky Monitor (ASM) between 1996 September 29 and October 8, consistent with the 186.5 day period (Corbet & Remillard 1996). The ASM data show a possible flare at the previous predicted outburst epoch, but with far less significance.

3 ASTROPHYSICAL PARAMETERS

By design, the $uvby\beta$ photometric system is most suitable for determining the stellar parameters in early-type stars. Unfortunately, the Be star case is complicated by emission from the circumstellar disc, so that the observed indices become functions of both the stellar parameters and of the disc parameters. Fabregat & Reglero (1990) determined transforms for the $uvby\beta$ indices to correct for circumstellar effects. The transforms are based upon the EW(Hα) parameter, which has been shown to correlate closely with circumstellar continuum and Balmer discontinuity emission (Dachs et al. 1986, 1988; Kaiser 1989).

The photometric *uvby* data used to derive the physical parameters were obtained from the first catalogue of the LTPV project at ESO (Manfroid et al. 1991), and correspond to three observations on 2nd and 5th January 1985. The errors are the mean value of the rms deviations of the differential measurements of those comparison stars having at least six observations in one run (Manfroid et al. 1991). We chose the photometric data as closely as possible to the optical minimum of 1984 (see Figure 3) since it is in this phase that the emission from the envelope is expected to be minimum. Consequently, the photometric magnitudes present the lowest contamination from the circumstellar emission. In addition, contemporaneus measurements of the Hα equivalent width were available from Cook & Warwick (1987b). The method and calibrations used to determine the physical parameters are explained in Reig et al. (1996a). In the present work, however, the value of the β index used corresponds to the mean for main-sequence stars, according to Equation 2 of Balona (1994). Mass was estimated by means of Balona's (1994) formula in terms of luminosity and effective temperature, which is based on the evolutionary models of Claret and Giménez (1992). The error quoted for the mass estimate is a formal error. The results are presented in Table 3.

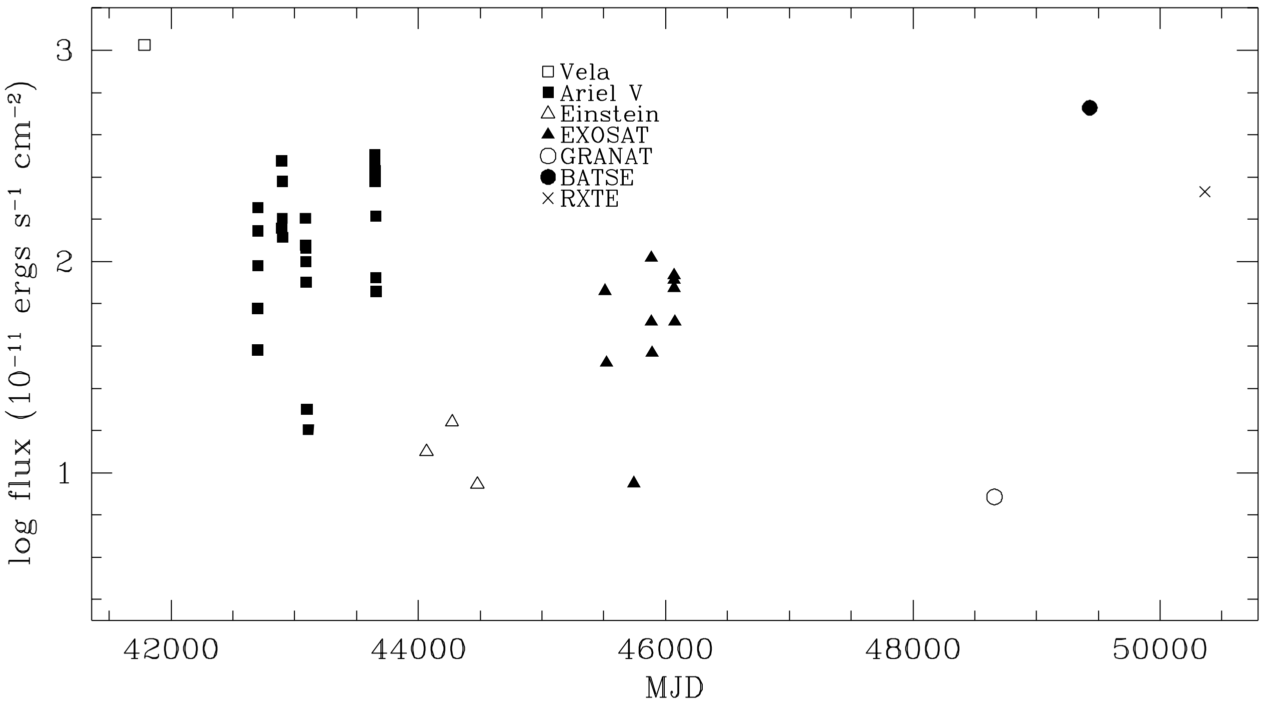

Figure 4. X-ray lightcurve of 4U1145-619 for the period 1973–1996, in the 2–10 keV range. All values except the *EXOSAT* ME points are calculated assuming a power law spectrum. This is to facilitate comparison of measurements made in different energy bands, and values may be in error by as much as a factor of 2 from one satellite to another. Note that the GRANAT point is an upper limit. References for X-ray data are: *Vela*, Priedhorsky & Terrel 1983; *Ariel V*, Watson, Warwick & Ricketts 1981; *Einstein*, Mereghetti et al. 1987; *EXOSAT*, Mereghetti et al. 1987; Cook & Warwick 1987a, 1987b; *GRANAT*, Grebenev et al. 1992; BATSE, Wilson et al. 1994; *RXTE*, Corbet & Remillard 1996.

Table 3. Derived astrophysical parameters of V801 Cen, the optical counterpart to the Be/X-ray binary 4U 1145-619

Spectral type	B1Ve
E(B-V)	0.29±0.02
T_{eff}	2.55±0.15 (10^4 K)
Mass	13±2 ($M_\odot$)
Radius	8±2 ($R_\odot$)
M_V	-3.1±0.5
M_{bol}	-5.6±0.5
$\log g$	3.8±0.2
Distance	3.1±0.5 kpc

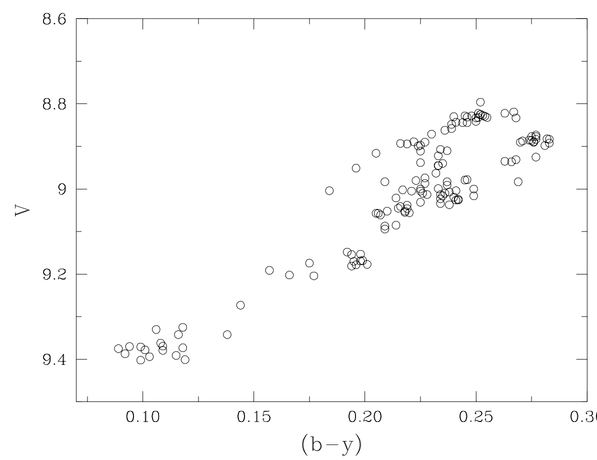

Figure 5. Colour-magnitude plot for V801 Cen, using y and $(b-y)$ data taken from ESO's Long Term Photometry of Variables Project catalogues (Sterken et al. 1995).

4 DISCUSSION

4.1 Optical and infrared variations

The infrared lightcurves in Figure 1 show the luminosity of the source to be decreasing in all bands throughout the period of the observations. Short term variations aside, the long term trend is a decrease of ~1 mag. The change in magnitude increases with wavelength, with the change in *J,H,K* and *L* approximately 0.7, 0.9, 0.9 and 1.3 respectively. The Hα and Hβ emission has been in decay during the same period, the one data point in exception being that of 1994 March 7, which is just 10 days (0.05 phase) before the maximum of the large X-ray outburst detected by BATSE. Observations have shown that the Balmer emission and the infrared excess characteristic of Be stars originate in

the same circumstellar disc (Dachs and Wamsteker, 1982). Hence a decrease in disc size would result in the observed variations in the infrared magnitudes and the Hα and Hβ emission. Also, as the disc's continuum is cooler than that of the photosphere, it is at longer wavelengths that we expect to see the largest variation in magnitude, again in agreement with the data.

In order to investigate the implications of the optical and infrared data presented here in the context of the past behaviour of the star, data were taken from the catalogue of ESO's Long Term Photometry of Variables project (Sterken et al. 1995). The data (Strömgren *uvby* photometry, covering the period 1982 to 1994) along with derived indices are shown in Figure 3, and were described in Section 2.3. Of note is the scale of the long term variability. The range of V magnitude is $\Delta V \sim 0.6$, whilst $\Delta(b–y) \sim 0.2$. As $(b–y)$ increases with optical luminosity, again the data indicate that the variations are greater at longer wavelengths. Figure 5 shows explicitly the relationship between luminosity and colour, represented by V and $(b-y)$ respectively. It is clear that in the high state, the $(b-y)$ index shows the star to be redder than in the low state. As with the infrared photometry then, the size of the variations and their dependance upon wavelength implies that they are the result of changes in the size of the circumstellar disc. Hence, with the new infrared and optical data we now have an indication of the way in which the disc has decayed, recovered and decayed again over the past 13 years from 1982 December to 1996 April.

The complete data set shows three disc loss episodes, corresponding to the two previously observed optical minima, and the current optical decay. Although the infrared and spectroscopic data in the period before our own observations is sparse, they are consistent with the timescale of disc loss and recovery suggested by the optical lightcurve. Similar episodes of disc loss have been observed in other Be/X-ray binary systems. Most notably, observations of X Persei have shown the Hα line changing from emission to absorption over a period of months (Norton et al. 1991). In the case of 4U1145-619, complete disc loss is clearly not the case at present, despite the decay in strength, because both the Hα and Hβ lines remain in emission.

4.2 X-ray behaviour

In Figure 3 the epochs of X-ray outbursts are plotted as arrows above the V band lightcurve. Again we define an outburst as an increase in flux by a factor of five above the quiescent flux of $\sim 10^{-10}$ ergs s^{-1} cm^{-2}. Six BATSE detections are plotted, these corresponding to the six penultimate arrows (Scott M. private communication). There appears to be a correlation between the X-ray and optical behaviour, with X-ray activity increased during periods of optical decline. Although we cannot however rule out the possibility that the apparent correlation is an artifact of the epochs of the X-ray observations, such a correlation is not unexpected, as the X-ray emission is fueled by the material in the varying disc. If the material lost from the disc is dissipated away from the star, rather than falling back onto the surface, then some fraction of this material should accrete onto the neutron star providing additional fuel for X-ray emission. This scenario was suggested by Roche et al. (1993) to explain similar correlations in the X-ray and optical/infrared behaviour of the Be/X-ray binary X Persei. Many Be/X-ray binary systems however show correlations of the opposite nature, with increased X-ray activity coinciding with optically bright phases (4U0115+63, Negueruela et al. 1997; A0538-66, Corbet et al. 1985). A distinguishing factor between these two groups is the significant difference in orbital period. Both 4U1145-619 and X Persei are long period binaries, with wide orbits, 4U0115+63 and A0538-66 each have periods less than 30 days, with much smaller orbits. In the case of the long period binaries, the neutron star may not become immersed in the disc during periastron passage, but rather accrete from the material that is lost radially from this disc during phases of decline in the Be star's activity. Such a scenario would be consistent with spherical accretion.

In such a binary, where the neutron star does not accrete directly from the Be star's disc, but from material lost radially from it, we might expect any orbital modulation of X-ray flux to be of smaller amplitude and smoother in profile than in systems where the neutron star becomes immersed in the disc at periastron. However in the case of 4U1145-619 the orbital modulation in the X-ray lightcurve is significant, with outbursts lasting less than 0.1 phase and increases in flux of an order of magnitude above quiescence. If this sharp modulation were caused by centrifugal inhibition of accretion (Stella, White & Rosner 1986), then we should not detect quiescent flux from the source. Corbet (1996) showed that X-ray emission may originate from the magnetosphere of the neutron star, even when accretion onto the neutron star surface was prohibited. We note that Corbet finds in the case of 4U1145-619, that this emission should be a factor of 7375 less than the minimum emission from the neutron star's surface. The quiescent flux observed in 4U1145-619 is only a factor of ~ 5 less than the normal outburst luminosity, suggesting that accretion onto the neutron star's surface is still occurring throughout the entire orbit. The sharp modulation may indicate an inclination between the planes of the orbit and the Be star's disc, the sharp modulation occuring as the neutron star's orbit crosses the plane of the disc at periastron.

4.3 Accretion mechanisms

The source's relatively low luminosity, wide orbit, and low pulsed fraction during 'minor' outbursts points towards spherical accretion as the source of energy for X-ray emission from 4U1145-619 (White et al. 1983). Arons & Lea (1980) suggested that the area of the accretion hot spot in accreting neutron stars increases as the X-ray luminosity decreases. For low-luminosity sources ($L_x \leq 5 \times 10^{36}$ erg s^{-1}), as is the case with 4U1145-619 during minor X-ray outbursts (see Figure 4), assuming the derived distance of 3.1 kpc, the accretion area can be as large as the entire surface of the neutron star. Therefore, the angular momentum of the flow in 4U1145-619 would be low and material would build up outside the magnetosphere before penetrating and falling unevenly over most of the surface of the neutron star.

The large outburst of 1994 March however allows an alternative scenario. At the maximum of the major outburst, the total flux detected by BATSE was 0.5-Crab (20–40 keV), with a significant phase averaged pulsed flux of 0.3-Crab

(Wilson et al. 1994), suggesting that in this instance at least, accretion was concentrated to a greater degree onto the magnetic poles. Such a difference in the pulsed fraction of the total flux could be interpreted as evidence for the formation of a short-lived accretion disc, which would allow more efficient binding of material to the magnetic field lines. In support of this hypothesis, the spin period of the neutron star was seen to decrease during the 1994 March outburst, whilst no significant spin-up was detected during the five less intense outbursts seen by BATSE between MJD 48361 and MJD 50231 (Scott M., private communication). This scenario would require a change in the circumstellar environment to account for the lack of accretion disc formation at other periastron passages. This requirement would be fulfilled by having a greater density of circumstellar material resulting from the proposed mass ejection event from the Be star. Further evidence for the formation of a temporary accretion disc comes from the fact that the March 1994 outburst continued at detectable levels longer than usual after maximum flux. Mereghetti et al. (1987) however give an alternative suggestion that such X-ray lightcurve profiles could be due to the compression of accreting material in the bow shock of the neutron star, followed by the accretion of more dilute "downstream" material. We also note that shortly before the BATSE detection in March 1994, the EW(Hα) strengthened to -45Å, with no correlated rise in the infrared luminosity. Either a delay exists between the reaction of the disc's Balmer emision and infrared excess, or an additional Hα component was present, with a source discrete from that of the infrared excess. An accretion disc could produce this Hα emission with no correlated change in the infrared magnitudes.

4.4 Astrophysical parameters

Comparing the astrophysical parameters calculated in Section 3 to previously published values yields few incompatibilities. The spectral type of B1 Ve is in agreement with previous classifications based on spectroscopic results. Previous values for $E(B-V)$ have been in the range $0.25 \leq E(B-V) \leq 0.45$, our value of 0.29 sits comfortably in the middle. The temperature of the star has been determined from a model atmosphere fit to an ultraviolet spectrum by Bianchi and Bernacca (1980). Their result of 22,000 K is not consistent with our value of 25,500±1,500 K (Bianchi and Bernacca quote no errors), but we must consider the difference of the methods used. The method used here has removed circumstellar effects using a transform involving the EW(Hα) index, whereas the method of Bianchi and Bernacca, whilst not corrected for circumstellar effects, was applied in the ultraviolet spectral region, where circumstellar effects may be expected to be minimal. However, Kaiser (1989) notes that fitting model atmospheres to Be star spectrophotometric measurements reveals systematic differences between the model and observations, and thus demonstrates the existence of radiation emitted by the envelope at ultraviolet wavelengths. The continuum emission of the disc is redder than that of the photosphere of the underlying Be star, and hence unless circumstellar effects are taken into account, stellar temperatures will be underestimated. The result which appears most discrepant with previously published values is the distance of 3.1 kpc, a factor of two larger than the generally accepted 1.5 kpc to this source (Hammerschlag-Hensberge et al. 1980; Lamb et al. 1980). Again there are significant differences in the methods employed in calculating the distance. Hammerschlag-Hensberge et al. find 1.6 kpc from the dereddening necessary to fit observed ultraviolet fluxes with expected spectra, but state that since colour excess is known to be insensitive to distance at this particular galactic longitude, the distance quoted may be in error by a factor of three or more.

5 CONCLUSIONS

The Be/X-ray binary 4U1145-619 is exhibiting signs of disc loss in optical and infrared wavelengths, after two previous such events since 1982. Whilst the infrared excess has decreased by $\Delta K \approx 1$, the disc does not appear to have been lost completely, as the Hα line still shows emission, the last observations showing EW(Hα) = -13 ± 1.3 Å. X-ray luminosities and pulse profiles during normal outbursts are typical of those expected for spherically accreting systems, though there is a possibility of the formation of a short-lived accretion disc during larger outbursts.

Physical parameters calculated for the optical counterpart V801 Cen show discrepancies with previously published values, but the discrepancies can usually be explained in terms of the circumstellar effects which need to be corrected for in the case of Be stars. Contemporaneous infrared and optical observations over the course of the next optical rise, combined with X-ray observations should confirm the existance or otherwise of any optical/X-ray correlations, and lead to a more complete understanding of the mechanisms fuelling this source, and long period Be/X-ray binaries in general.

Acknowledgments

We are grateful to staff at the SAAO for their assistance, and to Tom Marsh and Chris Moran for obtaining the AAT spectrum. Thanks also to the referee Reinhard Hanuschik for his comments on the original manuscript. Much helpful information regarding BATSE observations was provided by Matt Scott. This research has made use of the Simbad database operated at CDS, Strasbourg, France. Part of the data reduction and analysis was carried out on the Southampton University Starlink node which is funded by PPARC. JBS acknowledges the receipt of a research studentship from the University of Southampton.

REFERENCES

Arons J., Lea S.M., 1980, ApJ, 235, 1016
Balona L., 1994, MNRAS, 268, 119
Bianchi L., Bernacca P.L., 1980, A&A, 89, 214
Bradt H.V., & McClintock J., 1983, Ann. Rev. Astr. Astrophys., 21, 13
Bradt H.V. et al., 1977, Nature, 269, 21
Carter B.S., 1990, MNRAS, 241, 1
Claret A., Giménez A., A&AS 96, 255
Coe M.J., Everall C., Fabregat J., Gorrod M.J., Norton A.J., Reglero V., Roche P., Unger S., 1993, A&AS, 97, 245
Cook M.C., Warwick R.S., 1987a, MNRAS, 225, 369

Cook M.C., Warwick R.S., 1987b, MNRAS, 227, 661
Corbet R.H.D., Mason K.O., Branduardi-Raymont G., Cordova F.A., Parmar A.N., 1985, MNRAS, 212, 565
Corbet R.H.D, Remillard R., 1996, IAUC 6486
Corbet R.H.D, 1996, Ap J, 457 L31
Dachs J., Wamsteker W., 1982, A&A, 107, 240
Dachs J., Hanuschik R., Kaiser D., Rohe D., 1986, A&A, 159, 276
Dachs J., Kiehling R., Engels D., 1988, A&A, 194, 167
Densham R.H., Charles P.A., 1982, MNRAS, 201, 171
Dower R.G., Apparao, K.M.V., Bradt H.V., Doxsey R.E., Jernigan J.G., Kulik J., 1978, Nature, 273, 364
Fabregat J., Reglero V., 1990, MNRAS, 247, 407
Glass I.S., 1979, MNRAS, 187, 807
Grebenev S.A., Pavlinskii M.N., Syunyaev R.A, 1992, Sov. Astron. Lett., 18, 228
Hammerschlag-Hensberge G., et al. 1980 A&A, 85, 119
Hutchings J.B., Crampton D., Cowley A.P., 1981 AJ 86, 871
Jaschek M., Slettebak A., Jaschek C., 1981, Be Star Newsl., 4, 9
Jernigan J.G., Bradt H.,van Paradijs J., Rappaport S., 1978, IAUC 3225
Kaiser D., 1989, A&A, 222, 187
Lamb R.C., Markert T.H., Hartman R.C., Thompson D.J., Bignami G.F., 1980 ApJ, 239, 651
Manfroid J., et al., 1991, First Catalogue of Stars Measured in the Long-Term Photometry of Variables Project (1982-1986), ESO Scientific Report No. 8
Mereghetti S., Bignami G.F., Caraveo P.A., Goldwurm A., 1987, ApJ, 312, 755
Negueruela I., et al., 1997, MNRAS, 284, 859
Norton A.J., et al. 1991 MNRAS 253, 579
Pakull M., Motch C., Lub J., 1980 IAUC 3476
Priedhorsky W.C., Terrel J., 1983, ApJ, 273, 709
Reig P., Fabregat J., Coe M.J., Roche P., Chakrabarty D., Negueruela I., Steele I., 1996a, A&A, submitted
Reig P., Coe M.J., Stevens J.B., Negueruela I., Clark J.S., Buckley D.H.A., Fabregat J., Roche P., 1996b, 2nd Integral Workshop, The Transparent Universe, ESA SP-382
Roche P. et al., 1993, A&A, 270 122
Shortridge K., 1991, Starlink Miscellaneous User Document, 13, R.A.L.
Stella L., White N.E., Rosner R., 1986, ApJ, 308, 669
Sterken C., et al. 1995, A&AS 113, 31
Terrel J., Preidhorsky W., 1984 ApJ 285, L15
Warwick R.S., Watson M.G., Willingdale R., 1985, SSr, 40, 429
Waters L.B.F.M., Taylor A.R., van den Heuvel E.P.J., Habets G.M.H.J., Persi P., 1988 A&A 198, 200
Watson M.G., Warwick R.S., Ricketts M.J., 1981, MNRAS, 195, 197
White N.E., Swank J.H., Holt S.S., 1983, ApJ, 270, 711
White N.E., Parkes G.E., Sanford P.W., Mason K.O., Murdin P.G., 1978, Nature, 274, 664
White N.E., Becker R.H., Pravdo S.H., Boldt E.A., Holt S.S., Serlemitos P.J., 1980, ApJ, 239, 655
Wilson R.B., et al., 1994 IAUC 5955
Zhang S.N., et al., 1996, A&AS, accepted

This paper has been produced using the Royal Astronomical Society/Blackwell Science LaTeX style file.